APPENDIX C

DEVELOPMENT OF IDLE EMISSION FACTORS

Idle emission rates incorporated in California emissions inventory model, EMFAC2002, are based on test data from a limited number of vehicles. In addition, the emission test data were collected at "curb" idle without accessory loading. However, studies have shown idle emissions to be highly dependent on ambient conditions, accessory loading and engine speed (Lambert et al., 2001; Storey et al., 2003). Staff therefore modified the EMFAC2002 idle emission factors using emission test data obtained from two sources: (1) data from phase 1 of the CRC project E-55/E-59 (Gautam et al., 2003) and (2) data from a multi-agency study, which among others included the U.S. EPA and ORNL (Storey et al., 2003). The E-55/E-59 data were used to derive model year specific baseline emission factors at low idle with no accessory load and the U.S. EPA/ORNL data were used to develop correction factors to adjust the E-55/E-59 based unladen low idle emission factors to loaded high idle conditions.

E-55/E-59 Idle Emissions Data

The E-55/E-59 data used in this analysis represented idle emissions from 25 diesel powered heavy-duty trucks built between 1973 and 2000. Data were collected by West Virginia University at "curb" idle with no accessory loading. Each test was 15 minutes long and repeated at least three times. In developing the idle emissions factors, replicate tests were first averaged for each vehicle. The resulting vehicle specific average emissions were then plotted as a function of model year as shown in Figures C-1 to C-5. Except for NOx emissions, the graphs for PM, HC and CO showed emissions to decline by model year. The data points were then curve fitted to determine the best equation that represents the trend (Figures C-2 to C5).

NOx emissions showed two distinct groups of data points (Figure C-1). The first group, corresponding to pre 1990 model years, had lower NOx emissions while the second group, corresponding to model years 1990 and later, had higher NOx emissions. For each group, two average emission rates were calculated, one for pre 1990 model years and a second for 1990 and later model years. CO_2 emissions showed a linear but almost flat trend (Figure C-5), and therefore an average of all data points was calculated and applied to all model year groups.

For idle emissions of PM, HC and CO, the curve fit equations were used to calculate emissions for each model year between 1973 and 2000[1]. The resulting

[1] The curve fits are only valid for the range of values shown on each graph. In other words, these equations should not be used to predict or extrapolate emissions for model years outside the given range, as this could result in unrealistic emissions.

emissions were grouped by model year based on engine exhaust emission standards and then averaged for each model year group.

Figure C-1: NOx Idle Emissions

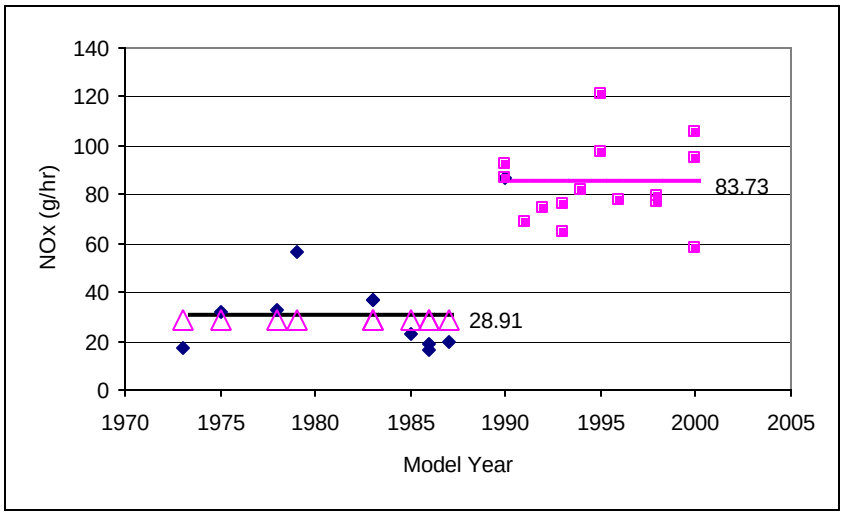


Figure C-2: PM Idle Emissions

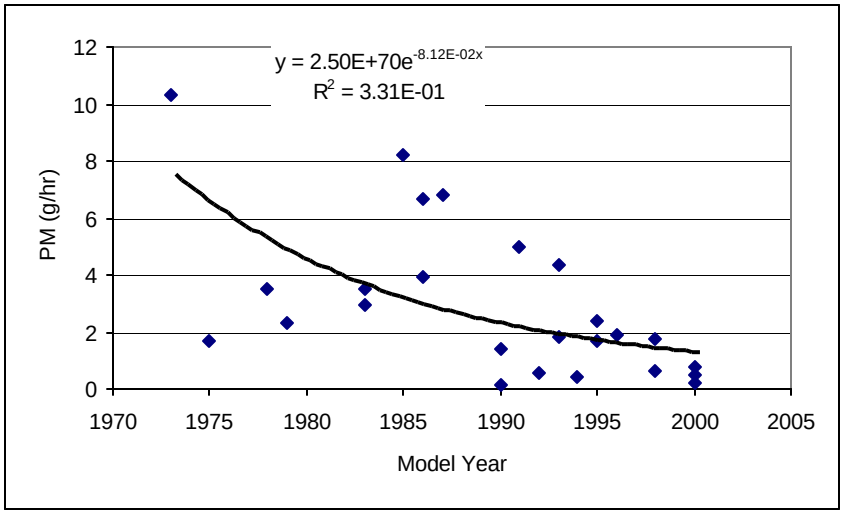


Figure C-3: HC Idle Emissions

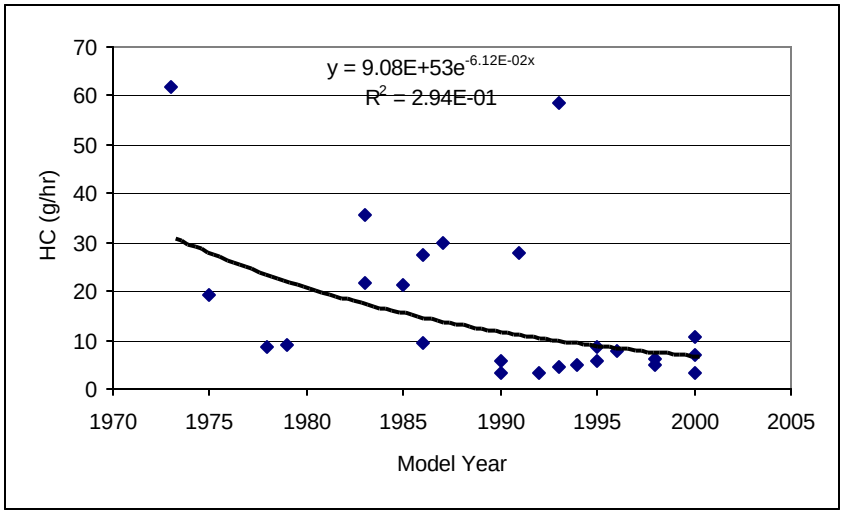


Figure C-4: CO Idle Emissions

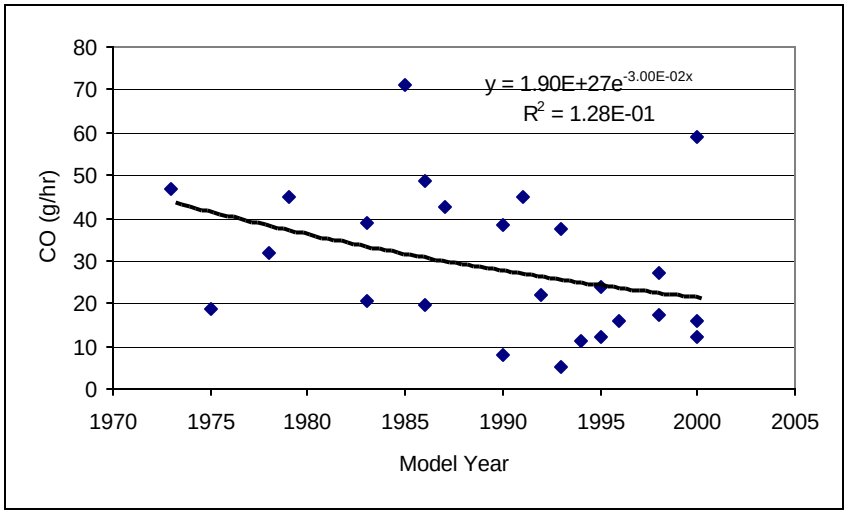
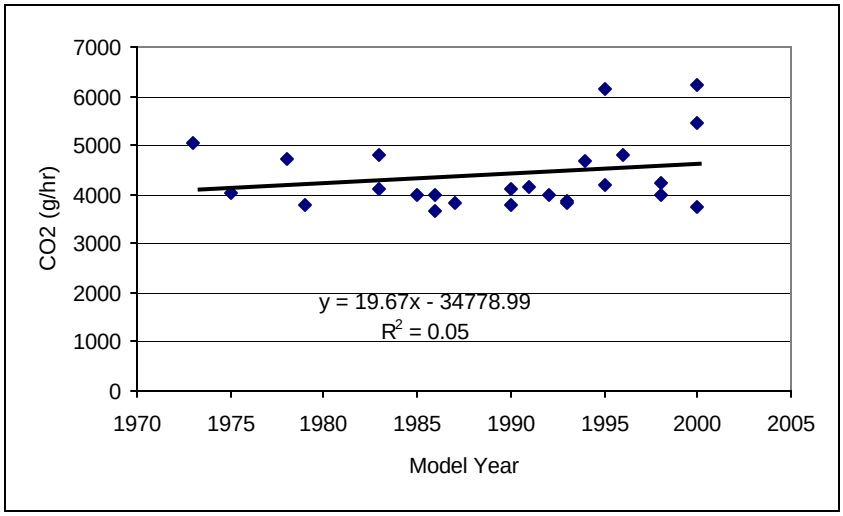


Figure C-5: CO_2 Idle Emissions



For 2004 and later model years, NOx, HC and CO emissions were assumed to remain equal to the 1998-2003 model year group emissions. This assumption follows from the conclusion that, as discussed on page 23, catalysts will have a minimal impact on reducing NOx, HC or CO emissions at the low exhaust temperatures that exist during idling.

PM idle emission factors for model year group 2004 to 2006 were assumed to remain equal to the 1998-2003 model-year group emission factors. However, for 2007 and later model years, PM idle emissions were adjusted to take into account the efficiency of the particulate trap that these vehicles will be equipped with to achieve the 0.01 g/bhp-hr PM exhaust standard. Table C-1 shows the resulting idle emissions factors by model-year group.

U.S. EPA/ORNL Emission Data

In this study, 5 heavy-duty diesel trucks were tested in an environmentally controlled chamber at low and high idle under three different conditions as follows: at 90ºF with the vehicle's air conditioning on, at 0ºF with the vehicle's heater on, and at 65ºF with no accessory loading. Staff analyzed the data published in the Society of Automotive Engineers (SAE) paper 2003-01-0289 and came up with a pollutant specific correction factor (CF) that can be applied to unladen low idle emission rates to get emission rates at high idle with accessory loading. Two factors were first determined: one correction factor (CF1) that applies for summer conditions, i.e., high idle and air conditioning use and a second one (CF2) that applies for winter conditions, i.e., high idle and heater use. CF1 was determined by dividing the average of the emissions at high idle with A/C use at an ambient condition of 90ºF by the average of the idle emissions at low idle (≤ 800 rpm) with no load and ambient condition of 65ºF. CF2 was

determined by dividing the average of the emissions at high idle with heater use at an ambient condition of 0ºF by the average of the emissions at low idle (≤ 800 rpm) with no load and ambient condition of 65ºF. An annual average correction factor, CF, was then determined by assuming 7 months of AC use and 5 months of heater use. CFs determined in this way are then applied to the idle emission rates obtained at low idle with no accessory load to obtain idle emission rates at high idle with accessory loads. Table C-2 shows the correction factors, CF1, CF2 and CF.

Table C-1: Idle Emission Factors by Model-Year Group at "Curb" Idle without Accessory Load (g/hr)

Model-Year Group	PM	NOx	CO	HC	CO2
2007+	0.09	84	18	6	4366
2004-2006	0.85	84	18	6	4366
1998-2003	0.85	84	18	6	4366
1994-1997	1.13	84	20	8	4366
1991-1993	1.50	84	23	9	4366
1990	2.00	84	25	12	4366
1987-1989	2.00	29	25	12	4366
1984-1986	2.65	29	28	14	4366
1980-1983	3.53	29	31	18	4366
1977-1979	4.68	29	35	22	4366
1975-1976	5.72	29	37	26	4366
Pre-1975	6.73	29	40	29	4366

Table C-2: Correction Factors for High Idle with Accessory Load

	PM	NOx	CO	HC	CO2
CF1	2.5	2.1	1.7	3.1	2.3
CF2	4.3	1.8	2.2	7.3	1.8
CF	**3.3**	**2.0**	**1.9**	**4.9**	**2.1**

High Idle Emission Factors

The pollutant specific correction factors in Table C-2 were then applied to the model year specific low idle emission factors in Table C-1 to get an annual weighted average high idle emission factors shown in Table C-3.

Table C-3: Idle Emission Factors by Model-Year Group at High Idle with Accessory Load (g/hr)

Model Year Group	PM	NOx	CO	HC	CO2
2007+	0.28	165	90	12	9140
2004-2006	2.77	165	90	12	9140
1998-2003	2.77	165	90	12	9140
1994-1997	3.69	165	100	15	9140
1991-1993	4.89	165	111	18	9140
1990	6.51	165	123	22	9140
1987-1989	6.51	57	123	22	9140
1984-1986	8.63	57	137	28	9140
1980-1983	11.49	57	152	34	9140
1977-1979	15.24	57	169	43	9140
1975-1976	18.64	57	182	50	9140
Pre-1975	21.92	57	193	56	9140

Estimating the Idling Emission Impacts

When estimating the emissions impacts due to idling of on-road heavy-duty diesel vehicles, the idle emission rates shown in tables C-2 and C-3 must be weighted by the fraction of vehicles that operate at high idle and the fraction of vehicles that operate at low idle. Although it is a common practice among truck drivers to operate the engine at high idle during extended idling periods, information or data documenting actual idle speeds is very limited. Staff looked at two sources of information: (1) a survey of 233 line-haul truck drivers conducted in Northern California by ITS, UC Davis, published in SAE 2001-01-2828 (Brodrick et al., 2001) and (2) a study presented at the 12th Annual On-Road Vehicle Emissions Workshop of the CRC, (Irick et al., 2002). Assuming engine speeds of 850 rpm and greater at high idle, staff analyzed the data reported in SAE 2001-01-2828 and concluded that approximately 61% of the drivers idle their engine at low idle while 39% percent idle their engines at high idle. In contrast, the CRC paper presented results from a nationwide survey of fleet managers and drivers and reported more than 70% of truck drivers idle their engines at 800 rpm or more. While the two studies have conflicting results, staff

determined that it would be more appropriate to use the results from the California specific (Brodrick) study. Thus, using the 61% low idle and 39% high idle weighting factors, the idle emission rates for an average on-road heavy-duty diesel vehicle are given in Table C-4.

Table C-4: Average Idle Emission Factors by Model-Year Group (g/hr)

Model Year Group	PM	NOx	CO	HC	CO2
2007+	0.14	109	41	8	5846
2004-2006	1.45	109	41	8	5846
1998-2003	1.45	109	41	8	5846
1994-1997	1.92	109	45	10	5846
1991-1993	2.55	109	50	12	5846
1990	3.40	109	56	15	5846
1987-1989	3.40	38	56	15	5846
1984-1986	4.50	38	62	19	5846
1980-1983	6.00	38	69	23	5846
1977-1979	7.95	38	76	28	5846
1975-1976	9.73	38	82	33	5846
Pre-1975	11.44	38	87	37	5846